Small Business Innovation Research/Small Business Tech Transfer

Load Responsive MLI: Thermal Insulation with High In-Atmosphere and On-Orbit Performance, Phase I

Completed Technology Project (2009 - 2009)

Project Introduction

Long term storage of cryopropellants with minimal loss is required for new Exploration spacecraft. Multi-Layer Insulation (MLI) is used to insulate cryotanks, but is a high risk for Earth Departure Stage and Altair propellant maintenance. An ultra-high performance thermal insulation, Integrated MLI, is being developed for NASA as an MLI replacement, and offers significantly improved thermal performance under space vacuum conditions. This proposal is for Load Responsive MLI (LRMLI), an innovative thermal system that under atmospheric pressure compresses dynamic Posts to support an integrated, thin vacuum shell for high performance in-atmosphere operation, then disconnects the Posts during on-orbit and Lunar surface operation to provide ultra-high performance thermal insulation. LRMLI will use micro-molded Center-Beam Tripod Posts between radiation barriers with a novel combination of low area-to-length spoke arms to reduce heat leak via conduction under no load, and a dynamic center beam to support a vacuum shell under load. For on-orbit space operation the theoretical thermal conductance is 0.22 W/m (e* = 0.00048). For in-atmosphere operation, atmospheric pressure compresses the Post until the center beam contacts the underlying layer, supporting an integrated 0.020" aluminum vacuum shell. The load bearing configuration has higher heat leak through the center beam (0.84 W/m), but has a heat leak 93X less than SOFI. LRMLI could offer superior on-orbit performance to MLI, much lower heat leak than SOFI during launch, and no need for N2 or He purge. Cryopropellant boiloff could be significantly reduced during pre-launch and launch operations, especially beneficial for Altair and EDS. In Phase I we would model, design, fabricate LRMLI prototypes and test thermal performance in vacuum and atmosphere, reaching TRL4. In Phase II we would move toward a commercially viable product and a TRL5.

Anticipated Benefits

Quest has studied commercial applications of our Integrated MLI insulation. Terrestrial non-NASA applications of Load Responsive MLI (LRMLI) are much greater since LRMLI operates efficiently in-atmosphere with an integrated vacuum shell. We have had discussions with dewar and appliance (refrigerator/freezer) manufacturers, who have shown good interest in this early stage insulation technology. Hydrogen powered aircraft are currently in design, with a critical aspect cryotank storage of LH2. Ball Aerospace conducted a trade study of insulations for a High Altitude Long Endurance aircraft, and found LRMLI to be by far the best insulation with lower mass and significantly lower heat leak than SOFI or MLI with heavy vacuum shell. Extremely efficient thermal insulation would have use in commercial cryogenic applications such as cryogenic vessels and pipes in scientific and industrial applications. A major use is insulating LN2, LHe and LOX dewars for research and industrial uses. Other potential applications include large commercial tanks, industrial boilers and industrial hot and cold process equipment, refrigerated trucks and trailers, insulated tank, container and rail cars, liquid

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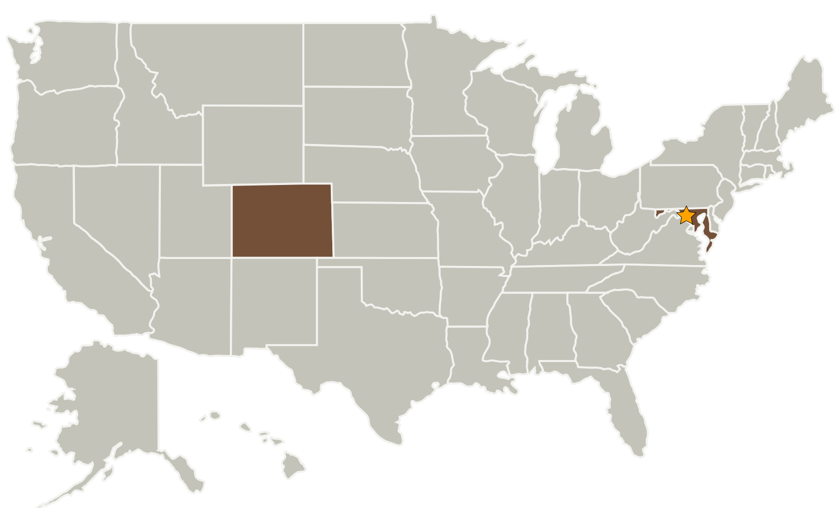
hydrogen fueled cars, appliances such as refrigerators and freezers, hot water heaters, mobile containers to keep foods hot or cold, marine refrigeration, potentially even house insulation. Load Responsive MLI (LRMLI) could provide dramatically improved thermal insulation for cryopropellant storage, especially during in-atmosphere launch and ascent. MLI has been identified as a high risk component for EDS and Altair vehicles. EDS requires minimal cryopropellant boiloff during launch and LEO operation. Altair also requires minimal losses during LEO and extended Lunar surface operations, and is difficult to top off prior to launch. Current thermal insulation designs use MLI, or SOFI/MLI combinations, and require purge systems to reduce losses and condensation in-atmosphere. Recent IRAD studies by Ball Aerospace indicate the total heat addition to the cryotank due to high heat leak of the purged and venting MLI is significant - up to 36% of heat leak for a 30 day mission. LRMLI could provide thermal insulation and integrated vacuum shell to insulate cryogenic systems on space instruments, satellites, spacecraft cabins and lunar surface habitats. LRMLI could provide micrometeorite protection. LRMLI should provide a high performance thermal insulation with adjustable thickness, mass and thermal conductance to fit mission requirements. It will provide inherent control of layer dimension and spacing, and should provide more predictable performance with less labor intensive assembly. It may be able to provide substantially longer term cryogenic storage, helping enable longer term manned space flights.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Goddard Space Flight Center (GSFC)

Responsible Program:

Small Business Innovation Research/Small Business Tech Transfer

Project Management

Program Director:

Jason L Kessler

Program Manager:

Carlos Torrez

Project Manager:

Shouvanik Mustafi

Principal Investigator:

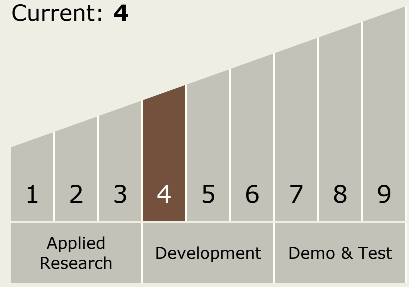
Scott Dye

Organizations Performing Work	Role	Type	Location
★Goddard Space Flight Center(GSFC)	Lead Organization	NASA Center	Greenbelt, Maryland
Quest Product Development Corporation	Supporting Organization	Industry	Arvada, Colorado
Quest Thermal Group	Supporting Organization	Industry	Arvada, Colorado

Primary U.S. Work Locations	
Colorado	Maryland

Technology Maturity (TRL)

Start: **4**
Current: **4**



Technology Areas

Primary:

- TX14 Thermal Management Systems
  └ TX14.1 Cryogenic Systems
    └ TX14.1.2 Launch Vehicle Propellant